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# 7

## Mat Problems

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### Learning Outcomes:

- ☐ Identify QA techniques that apply to asphalt construction (laydown and compaction)
- ☐ Recognize causes of defects

### Mat Problems

Mat problems can be defined as defects that occur in the asphalt mixture during or soon after the laydown and compaction operations have been completed.

These problems fall into two primary categories:

1. Equipment-related problems and
2. Mixture-related problems

In this chapter, major mat problems are reviewed and a description of each problem is presented, including its causes, solutions and effects on long-term pavement performance. Only those problems that occur at the time of the asphalt mix production, laydown and compaction will be addressed. A number of other deficiencies can occur on an asphalt pavement structure with time and traffic loading once construction has been completed.

## Segregation

Hot mix asphalt mixtures that are properly designed, produced, and placed provide a durable, long lasting pavement that requires very little maintenance. However, there are a number of potentially damaging problems that can occur in the design, production and placement of hot mix paving mixtures.

Of these problems, perhaps the most serious one is segregation. Segregation is a frequently recurring problem that has caused concern within the paving industry for decades and is receiving widespread attention by contractors, State Highway Departments and equipment manufacturers.

When segregation is present in a mixture, there is a concentration of coarse materials in some areas and finer materials in the other areas of the paved mat. Segregation creates non-uniform mixes that do not conform to the original job mix formula in gradation or PG binder. The resulting pavement exhibits poor structural and texture characteristics and has a shorter life expectancy. Problems associated with segregation are serious, and their elimination is essential to the production of high quality paving mixtures.

Elimination of segregation is the responsibility of those who produce and lay asphalt mix, those State Highway Departments who design the mix and inspect the final product, and those manufacturers who design and market machinery for the paving industry.

Proper mix design is important in the effort to eliminate segregation. Mixes that are uniformly designed with no gap grading are generally more forgiving.

Asphalt Concrete Mixtures – Design Range										
Percentage by Weight passing Square Mesh Sieves (in)										
Type	% by Mass Passing Square Mesh Sieves									
	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No 4	No 8	No 30	No 50	No 200
SM-9.0, A, D, E				100*	90-100	90 max	47-67			2-10
SM-9.5, A, D, E				100*	90-100	80 max	38-67			2-10
SM – 1 2.5, A, D, E			100	95-100	90 max	---	34-50			2-10
IM-19.0 A, D		100	90-100	90 max	---	---	28-49			2-8
BM-25.0 A, D	100	90-100	90 max	---	---	---	19-38			1-7
C (Curb Mix)				100	92-100	70-75	50-60	28-36	15-20	7-9
Legend: SM = Surface Mixture; IM = Intermediate Mixture; BM = Base Mixture; C = Curb Mixture										
*A production tolerance of 1% will be applied to this sieve, regardless of the number of tests in the lot.										

Gap graded mixes are by the same token unforgiving and any slight error in the plant, trucking or laydown process can result in non-uniform surfaces. If the mix is gap graded to a sufficient degree with a low PG binder, it simply cannot be produced without segregation occurring regardless of the techniques used.

Segregation can also be caused by improper paver operation. Some likely contributing factors are:

- Unbalanced paver demand
- Drawing hopper empty between loads
- Dumping hopper wings between loads
- Truck not dumping to fill hopper
- Spot segregation during truck loading

When loading a truck into a paver hopper, it is important to discharge the material as a mass instead of dribbling the material into the paver. To accomplish this objective, the bottom of the truck bed needs to be maintained in good condition and be lubricated so that the entire load will slide rearward. To further assure that the material is discharged as a mass, evaluate the truck bed to a large but safe angle.

Rapid truck discharge floods the paver hopper and minimizes material run around that often occurs at the tailgate ends. This rapid discharge stops an accumulation of coarse material at the outside portion of the paver wings.

Even though material is successfully processed through the cold feed bin, the plant, the surge or storage bin and then uniformly loaded on the truck, segregation can still occur in the asphalt paving machine. Improper operation of a paver can cause segregation in varying degrees.



### **Consideration When Segregation is Occurring at the Paver**

Dump hopper wings only as required to level the material load in the hopper. This dumping eliminates the valleys in the material bed, thus minimizing the rolling that occurs with unloading and allows the truck tailgate to swing open fully to flood the hopper with mix.

Open hopper gates as wide as possible to insure the augers are full. By closing the gates and starving the augers for mix, fine material will drop directly on the ground causing coarse materials to be channeled to each side.

Run the paver as continuously as possible. Start and stop only as necessary. Adjust the paver speed to balance paver production with plant production.

Run augers continuously. Auger speed should be adjusted so that a continuous, slow flow of material occurs. Augers that run at high speeds are cycling on and off continuously and contribute significantly to segregation at the paver. If augers are running too fast, the center of the mat will be deficient of material and this will generally result in a coarse strip.

If possible, adjust paver extensions so that the paver pulls the same amount of material from each side of the hopper. If one side is pulling a much higher amount of material, a valley will form in that side of the paver hopper causing segregation to occur in sensitive mixes. If correction cannot be made by adjusting the extension, offset the truck slightly to even out the material bed in the hopper.

Excessive handwork can turn a smooth mat into a segregated mat. Keep handwork to a minimum.

[illegible]

### Chart for Mat Problems and Causes

<b>OTHER PROBLEMS TO BE INVESTIGATED</b>		<b>CAUSE</b>	<b>EFFECTS</b>	<b>SOLUTIONS</b>
		<b>PROBLEM</b>	<b>COLD MIX TEMPERATURE</b>	<b>VARIATION OF MIX TEMPERATURE</b>
		Wavy Surface- Short Waves (Ripples)	X	X
		Wavy Surface – Long Waves	X	X
		Tearing of Mat – Full Width	X	X
		Tearing of Mat – Center Streak		X
		Tearing of Mat - Outside Streaks		X
		Mat Texture – Non-Uniform	X	X
		Screed Marks	X	
		Screed Not Responding to Correction	X	X
		Auger Shadows		X
		Poor Precompaction	X	X
		Poor Longitudinal Joint		X
		Poor Transverse Joint	X	X
		Transverse Cracking (Checking)		X
		Mat Shoving Under Roller	X	X
		Bleeding or Fat Spots in Mat		X
		Roller Marks		X
		Poor Mix Compaction		X

## Surface Waves

An asphalt surface can have two types of waves: short and long.

- Short waves, also sometimes called rippers or auger shadows, are generally one to three (1-3) feet apart, with one and one half to two (1.5-2) feet being the most common separation.
- Long waves are considerably farther apart. The distance between them may correspond to the distance between truck loads of mix. Long waves may also be associated with the reversal points of the compaction equipment, particularly on thick-lift construction or when the AC being placed is tender and moving longitudinally under the compaction equipment.



An additional type of defect in the pavement surface is a roughness or washboard effect caused by improper operation of a vibratory roller. The distance between the waves is generally very small, typically less than three or four (3 or 4) inches.

### (a) Causes

- A major cause of short waves or ripples is a fluctuating head of material in front of the paver screed. The variation in the amount of mix being carried back to the augers by the slat conveyors and deposited in front of the screed causes the screed to rise and fall as the force pushing against it changes. Too much mix (at the top of the augers) and then too little mix (at the bottom of the augers) being carried in the auger chamber in front of the screed causes the wavy surface as the screed reacts to the variation in force. The fluctuating head of material causes the screed to rotate around its pivot point and “hunt” for an angle of attack. As the angle of attack of the screed changes, the thickness of the mat being placed also changes, and the smoothness of the new layer is directly affected.
- Another cause of short waves is a screed that is poor mechanical condition – one with excessive play in the screed control connections. Short waves can also be formed in the

mat by improper mounting or sensitivity of the automatic grade control on the paver or by use of an inadequate grade reference device. The problem may also be related to a mobile reference (floating beam) that is bouncing, or the truck driver's holding the brakes while the truck is being pushed by the paver.

- Short waves can also be related to the mix design, particularly with a mix that varies in stiffness as a result of changes in the mix temperature or composition. As the stiffness of the mix varies, the forces of the mix pushing on the screed vary as well, causing the screed to rise and fall which results in a mat with short waves. Finally, if the mix design is improper in aggregate gradation, asphalt content, mix temperature or moisture content (the mix is tender), the rollers may shove and displace the mix during the compaction process. Normally, however, short waves are placed in the mat by the paver because of either its operation or changes in mix stiffness, rather than by the operation of the compaction equipment.
- Long waves are caused by some of the same variables that result in short waves. Fluctuation in the amount of material in front of the screed and variation in mix stiffness caused the screed to react to the change in the force exerted on it. If the distance between the wave peaks corresponds to the length of pavement between truckloads of mix, however, the waves may have been caused by incorrectly set hopper flow gates on the paver or by the paver hopper and slat conveyors being emptied between loads of mix. Poor mechanical condition and improper operation of the screed (continually changing the manual thickness control cranks, for example), as well as incorrectly mounted automatic grade controls, can cause a long-wave problem. If a stringline is being used as a grade reference, a sag in that line between support posts can also be a cause of long waves. Another factor contributing to long-wave roughness is improper delivery of the mix to the paver, particularly if the haul truck bumps into the paver or if the truck driver holds the brakes while the truck is being pushed by the paver. One additional factor can be the condition of the underlying surface: the long waves may be a reflection of the waves in the base material.
- Long waves may also be found at those points where the compaction equipment reverses direction. This problem is most prevalent when the asphalt layer being placed is more than about four inches thick. The problem may be exacerbated when the maximum-size aggregate used in the mix is relatively small compared with the lift

thickness. The waves are caused by a bow wave that forms in front of the roller when the mix is tender.

- In terms of mix design, long waved can be caused by truckload-to-truckload segregation of the mix and by changes in the mix temperature. Both deficiencies cause the forces on the screed to vary, resulting in a wavy surface. The compaction equipment can also create a wavy mat if the roller operator turns or reverses the machine too abruptly.
- Roughness or washboarding is normally caused by improper operation of a vibratory roller. This type of equipment should be operated at as high a frequency as possible and at an amplitude setting related to the thickness of the layer being compacted – usually a higher amplitude setting for a thicker layer of mix and a lower amplitude setting for a thinner lift. Further, the washboard effect can be worse if the roller is operated a high speed, particularly if the frequency setting is less than 2,400 per minute.

#### **(b) Solutions**

- Short waves (ripples) can be eliminated only by preventing their formation. The most important factor in preventing short waves is to keep the amount of mix (head of material) in front of the screed as consistent as possible. In addition, the stiffness of the mix, which is related to both its temperature and its composition, should be maintained as constant as possible. The amount of mix is controlled by properly setting the hopper flow gates and by keeping the slat conveyors and augers operating as much of the time as possible (close to 100 percent) while the machine is moving forward. Mix stiffness is controlled at the asphalt plant by keeping the mix temperature, aggregate gradation, and fluids content (asphalt content plus moisture content) as consistent as possible. Any factors that cause either the volume or stiffness of the mix at the screed to change can cause short waves or ripples in the AC mat.
- Surface waves caused by problems with automatic grade controls can be detected by shutting off the grade controls and determining whether the waves continue to form. If the grade controls area at fault, the operation and maintenance manual supplied with those controls should be consulted to determine the proper corrective action. Sags in a stringline reference can be found by sighting down the line as the grade sensor wand passes along the string. Short or long waves caused by the mechanical condition or operation of the paver screed can usually be detected by careful observation of the

paver during mix laydown. The long waves formed by incorrect operation of the haul truck or compaction equipment can also be detected easily by observing those operations.

- If washboarding is caused by incorrect operation of a vibratory roller, a change should be made in one or more of the following: the vibratory amplitude setting, the vibratory frequency, and the speed of the roller.

### **(c) Effects on Long-Term Pavement Performance**

Long-term pavement performance is affected by surface waves, both short and long, in two ways.

1. The waves reduce the smoothness of the pavement, which lowers the pavement condition rating or the present serviceability index of the roadway. The structural performance of the pavement will be changed, however, only if the waves are severe enough to increase the dynamic or impact loading of the pavement under heavy truck traffic.
2. Short waves and the factors that cause them can affect pavement density levels. A tender mix is generally more difficult to compact properly than is a stable mix; the result may be a decrease in density and a corresponding increase in air void content.

Washboarding is basically toughness built into the pavement surface during the compaction operation. Because it affects the degree of density obtained during the compaction process, this type of defect can significantly reduce the long-term durability of the pavement layer. In addition, washboarding contributes to a rough ride for the vehicles using the pavement.

## Tearing (Streaks)

There are three general types of mat tearing or pulling of the asphalt mix under the screed of the paver. The three types are defined by the location of the tear marks in the mat:

1. In the center of the lane
2. On the outside edges, and
3. Across the full lane width



### (a) Causes

- A gearbox streak can sometimes be seen in the surface of the mat directly behind the center of the main screed. This streak is typically six to eight (6-8) inches wide and is normally caused by a lack of asphalt mix being pushed under the auger gearbox located in front of the center of the screed. This lack of mix may be the result of improper flow gate settings – not enough mix being fed back to the screed. It is more likely to be caused, however, by missing, worn, or improperly set reverse augers or paddles on the augers (located adjacent to the gearbox) that are used to force mix underneath the gearbox.
- A gearbox streak is often thought to be a type of segregation. It is not. The rough surface texture is the result of lack of mix at the point in the pavement width – less mix passes under the screed at the auger gearbox than passes under the screed on either side of the gearbox. The rougher texture, or tearing, makes the surface appear more open or segregated. Gearbox streaks are more prevalent with harsher mixes – those containing larger-size aggregate, more crushed aggregate, or lesser amounts of asphalt.
- A centerline streak can also be caused by improper setting of the crown on the main paver screed. The appearance of streaks behind the screed is caused primarily by an improper relationship between the crows at the leading (front) and trailing (back) edges of the screed. A tearing or open texture about a meter (several feet) wide in the center of the mat may be caused by a lack of lead crown in the screed. Conversely, a tearing or open texture along both outside edges of the asphalt mixture is normally caused by an excess of lead crown in the screed. For most mixes the lead crown of the screed should



be set slightly higher- (approximately one eighth of an inch (1/8 inch) - than the tail crown. A proper relationship between lead and tail crowns will result in a uniform texture of the mat across its full width. Edge streaks can be caused by improper flow gate settings or incorrect installation of the screed extensions. Partial-width tearing can also result from a cold screed plate if the screed has not been uniformly preheated before paving begins.

- Full-width tearing of the mat can be attributed to a number of factors. One such factor is warped or worn screed plates. Another is the forward speed of the power being too high for a particular mix. The use of a mixture with aggregate that is large compared with the mat thickness being laid can also be responsible for full-width tearing of the mat. A good rule of thumb for the relationship between the maximum aggregate size in the mix and the minimum compacted course thickness is that the depth of the compacted layer should be at least twice the largest coarse aggregate particle size or three times the nominal maximum aggregate size. Thus a mix containing a maximum aggregate size of three quarters (3/4) of an inch should be placed at least one and a half (1 1/2) inch thick. Lastly, cold mix temperatures, particularly when combined with a cold paver screed, can significantly affect the amount of tearing that occurs.

#### **(b) Solutions**

- A gearbox streak can usually be eliminated only by changing the amount of mix being forced under the screed at the auger gearbox. This change is made by installing reverse paddles or reverse augers on each side of the gearbox in order to push more mix under the gearbox. If the paver is already equipped with such devices, they should be checked to see whether they are worn and need to be replaced.
- Constant center or outside edge mat tearing can usually be eliminated by adjusting the relationship between the lead and tail crowns on the paver screed. If this change does not solve the problem, the setting of the paver flow gates should be modified. Full-width tearing can be eliminated by increasing the mix temperature, preheating the screed properly before paving starts, replacing warped or worn screed plates, or increasing the lift thickness.

**(c) Effects on Long-Term Pavement Performance**

Tearing of the mat affects long-term pavement performance by causing changes in density in those areas where the tearing has occurred. Torn areas may appear segregated and are usually deficient in mix quantity. Pavement performance will be reduced in relation to the degree to which the tearing reduces the density and increases the air void content of the mat. In addition, the torn areas will be more susceptible to raveling and to the effects of moisture (stripping).

**Checking**

Checking can be defined as short transverse cracks, usually one to three (1-3) inches in length and one to three (1-3) inches apart, which occur in the surface of the AC mat at some time during the compaction process. The checks are not visible immediately behind the paver screed. Rarely does checking occur during the first or second pass of the compaction equipment over the mat. If checking is going to occur, it will normally take place after the mix has cooled to a temperature of less than 240°F and additional passes of vibratory or static steel wheel rollers (or both) are made over the mat. Checking does not usually occur when the mix is compacted with a pneumatic tire roller.

Most AC mixtures do not check at all during compaction, whereas others exhibit tender characteristics and check readily. As checking becomes severe, the cracks become longer and are spaced closer together. The cracks do not extend completely through the depth of the course, but are only three eighths (3/8) to one half (1/2) inch deep.

**(a) Causes**

- A mix that checks during compaction is a tender mix. The mix shoves or moves in front of the drums on either vibratory or static steel wheel rollers. Checks or cracks are formed when a bow wave occurs in front of the roller drums as the mix moves longitudinally before the roller reaches that location.
- Checking may be caused by two primary factors: (a) excessive deflection of the pavement structure under the compaction equipment and (b) one or more deficiencies in the asphalt mix design. A mix that checks is not internally stable enough – does not have enough internal strength at elevated temperatures – to support the weight of the compaction equipment during the rolling process.
- When a yielding foundation is the cause of the checking problem, the underlying pavement on which the new AC layer is being placed is weak and yields under the

movement of the compaction equipment. The weight of the rollers causes the layers in the pavement structure to move, shove, and bend excessively, placing the new mix in tension at its surface. The check marks are then formed when the surface of the new AC is pulled apart as the pavement structure deflects during the rolling operation. The checks should appear in the new mix surface only at locations where there is movement of the pavement structure under the compaction equipment. If the paver passes over a soft spot in the underlying structure, for example, the checking should occur only where the soft spot exists.

- A more common cause of checking is one or more deficiencies in the AC mixture: (a) an excess of fluids in the mix – too much asphalt cement or too much moisture in the mix, or both; (b) a hump in the sand gradation curve – too much midsize sand material and too little fine sand material and (c) a lack of room in the aggregate gradation for the asphalt cement (low VMA).
- An excess of fluids in the AC mix makes the mix tender and allows it to be displaced easily under the applied compaction effort of the rollers. The mix will be tender if the binder content is too high for the gradation and characteristics of the aggregate used, particularly if the mix has a low VMA content. If the mix contains too much moisture because the aggregate was not completely dried when passing through the batch plant drier or drum mixer (parallel flow or counter flow), the excess moisture will act as asphalt cement at elevated temperatures and over lubricate the mix. The moisture remaining in the aggregate pores will prevent the binder material from entering those pores in the aggregate in effect leaving more binder material between the aggregate particles instead of partly inside the aggregate.

**(b) Solutions**

- If checking is caused by the presence of a yielding foundation underneath the new AC layer, the solution is to repair and properly prepare the existing pavement structure before the new AC layer is placed. Soft spots should be removed and replaced. All areas of excessive deflection should be removed and replaced or stabilized. Uniform support is needed in the underlying pavement structure if the new pavement layers are to perform adequately.
- If checking is caused by a deficiency in the mix design – an excess of fluids in the mix or a problem with the gradation of the fine aggregate or the VMA content of the mix – the

long-term solution is to change the mix properties. Those changes must be made at the asphalt plant and cannot be made at the paving site. If the mix contains an excess of fluids – either asphalt cement or moisture – the binder content should be reduced or the aggregate properly dried to remove all of the moisture. In some cases, the production rate of the plant will have to be reduced for the moisture to be completely removed from the aggregate. In other cases, plant operating conditions may need to be changed (e.g., flights, drum angle).

- If checking is caused by the gradation of the fine aggregate incorporated into the mix, the gradation should be changed. It may be necessary to increase or decrease the amount of fine aggregate used, add a small amount of fine aggregate with a different gradation, increase the angularity of the fine aggregate, or use a completely different material from a different source. If checking is caused by a lack of VMA in the AC mix, changes need to be made to increase the VMA.
- Checking is often thought to result from the mix being too hot. This is only partially correct; the mix is too hot at some temperatures to support the weight of the compaction equipment because the mix lacks internal strength and stability. If the mix were properly designed, it would not be too hot to be compacted at any temperature below about 300°F. Most checking occurs when the mix temperature is decreasing from about 240°F down to about 190°F; rarely does checking occur when the mix temperature is above approximately 240°F or below approximately 190°F.
- In the short term, changes in both the rolling zone and the type of rollers used to densify the mix can be made to reduce the amount of checking that occurs. If the mix is tender because of excess fluids, a problem with the fine aggregate gradation, or lack of BMA, it may be possible to densify the mix properly at an elevated temperature without causing the checking.
- A mix that checks is tender, but this mix can usually be compacted satisfactorily at high temperatures – above 250°F. The required level of density can generally be obtained if enough roller passes can be applied to the mix before it cools to the point at which the checking begins. This can be done by using two breakdown rollers instead of one – using two rollers operating in echelon (side by side) instead of using a breakdown roller followed by an intermediate roller. The two breakdown rollers each apply their compactive effort to one side of the newly placed lane. Many passes are made over

each point in the pavement surface before the mix begins to check. Once checking starts the rolling process is temporarily suspended.

- If compaction operations are attempted when the mix is moving, shoving, and checking under the action of vibratory or static steel wheel rollers, the mix will decompact rather than compact. Rolling should not be carried out with steel wheel rollers when the mix is tender and checking. Most tender mixes will remain tender until the surface of the mix cools to a temperature of approximately 190°F. At this temperature, the mix has cooled sufficiently so that the viscosity of the asphalt binder has increased to the point where the mix can again support the weight of the compaction equipment. Static steel wheel rollers can then be used to achieve the final density in the mix and remove any roller marks in the pavement surface.
- When a tender mix is in the middle temperature range, between about 240°F and 190°F, rolling should not be attempted as discussed above, with either vibratory or static steel wheel rollers. A pneumatic tire roller, however, can be used in this temperature zone since the rubber tires on this roller will typically not shove the mix and a bow wave will not form in front of the tires. The tender mix will densify, instead of check, under the compactive effort of the pneumatic tire roller. Finish rolling using a static steel wheel roller can be completed once the mix has cooled to a temperature below about 190°F.
- In most cases, when checking occurs in the mix, the roller operators tend to back off the mix and allow it to cool. This is the wrong approach to the problem. Delaying the compaction permits the mix to cool and stiffen but most often does not then allow enough time for the mix to achieve the required level of density. With a tender mix, it may not be possible to accomplish both objectives (no checking and adequate density) at the same time if the mix is allowed to cool before rolling operations if the mix is allowed to cool before rolling operations are started. It is much better to compact the mix as much as possible before checking starts, stay off the mix in the middle temperature zone when checking is most likely to occur, and then finish roll the mix once it has cooled enough to support the weight of the final roller.
- If the mix delivered to the paver is too hot – above 325°F – it should be allowed to cool after laydown before the compaction process is started. Improper rolling techniques should be corrected. The surface of the underlying pavement should be clean and properly tack coated before placement of the new mix begins.

- None of the solutions to the checking problem will work in all cases. Each mix will have its own compaction characteristics. For some extremely tender mixes, checking may occur at a wider range of temperatures, from as high as 270°F down to as low as 170°F. As noted, mixes that lack internal stability will generally check under steel wheel rollers (operated in either the vibratory or static modes) and thus these mixes should be redesigned.

**(c) Effects on Long-Term Pavement Performance**

Although checks extend only a short distance down from the surface, they are highly detrimental to long-term performance because the tender mix characteristics affect the level of density obtained. If the rollers are kept back from the paver in an attempt to decrease the amount of checking that occurs, the level of density obtained by the compaction equipment will normally be reduced significantly. Thus the air void content of the AC mat will increase. A mix that contains checks will therefore lack density and have a greatly reduced pavement life under traffic.

**Non-uniform Texture**

Non-uniform mat texture can be described as differences in the appearance of the mix, both transversely and longitudinally, as it is placed and compacted. Normally, minor differences in surface texture will be apparent because of differences in the alignment of the larger coarse aggregate particles as the mix passes out from beneath the paver screed. In addition, a mix with a higher fine aggregate (sand) content will have a more uniform surface texture than a mix containing a larger percentage of coarse aggregate.

**(a) Causes**

- Many factors related to the operation of the asphalt paver affect the uniformity of the surface texture of the mix. A variable amount of mix against the screed, caused by overloading the augers or running the hopper empty between truckloads, can cause variations in the amount of mix tucked under the screed and thus produce a non-uniform texture. Improper screed maintenance, including worn or loose screed plates or screed extensions incorrectly installed, as well as low screed vibratory frequency, may alter the mat texture and cause non-uniformity. In addition, a low mix temperature, caused either by plant problems or by the paver sitting too long between truckloads of mix, can be a factor in uneven mat texture, especially if the paver screed is also cold. The tearing that

results when the compacted layer thickness is less than twice the dimension of the largest aggregate particles (as discussed above) is still another contributing factor.

- A soft or yielding base under the course being constructed may cause the new layer to have a variable surface texture. Moreover, segregation of the mix caused by poor mix design or improper handling of the mix during mixing, loading, hauling, unloading, or placing operations can contribute to a non-uniform surface texture. The variability of the texture will be affected as well by any factors that cause non-uniformity in the mix, such as deviations in aggregate gradation, asphalt content, or mix temperature.

#### **(b) Solutions**

- The solutions for non-uniform surface texture are as varied as the causes. Paver operation, particularly with regard to the need for a constant head of material in front of the screed, should be monitored closely. The paver and screed should both be well maintained and in good operating condition. The compacted thickness of the mat being placed should be designed so that it is at least twice the size of the largest coarse aggregate particles incorporated into the mix. Finally, a mix that is tender, variable in aggregate gradation or asphalt content or easily segregated should be modified to increase its stiffness and improve its properties before it is produced at the plant and delivered to the paver for laydown.

#### **(c) Effects on Long-Term Pavement Performance**

Non-uniform surface texture is usually associated with non-uniform density. The same compactive effort will generally achieve lower density in areas in which the coarse aggregate has been dragged by the paver screed or segregation of the mix has occurred, as compared with areas having uniform surface texture. As density decreases and air void content increases, the durability and serviceability of the asphalt mat decrease markedly.

## Screed Marks

Screed marks are transverse indentations in the surface of the asphalt mat. They occur when the paver stops between truckloads of mix. Depending on the mixture being placed, some screed marks are barely noticeable, whereas others are very distinct and deep. Screed marks can also occur in the longitudinal direction when rigid or hydraulic extensions are used and the elevation of the extension is not the same as that of the main screed.

### (a) Causes

- There are several causes of transverse screed marks. One is excessive play in the mechanical connections on the screed. Such marks also result when the screed is set up incorrectly and rides heavily on its rear end. If the asphalt mix is tender and if the paver is equipped with a very heavy screed, such as hydraulic extensions with additional rigid extensions attached, the screed will tend to settle into the mix and leave marks. If any of these causes are involved, the screed marks will be visible each time the paver stops.
- Another cause is the haul truck bumping into the paver when preparing to discharge the mix or the truck driver holding the brakes on the truck when the paver starts to push the truck. In these cases, the screed marks will appear only when the truck – paver interchange is improper.
- Longitudinal screed marks are caused by improper setting of the screed extensions relative to the main screed. When extensions are used, their vertical position and angle of attack must be the same as those of the main screed. If rigid extensions are set at the wrong elevation, a longitudinal mark will occur at the point where the different screed sections are joined. If hydraulic extensions are used, two longitudinal marks may occur – one at the end of the main screed and one at the inside edge of the extension on each side of the machine.





**(b) Solutions**

- If the transverse screed marks are a result of the mechanical condition or improper setup of the paver screed, the screed should be repaired. If the marks are caused by the truck bumping into the paver, the laydown operation should be altered so that the paver picks up the haul truck instead of the truck backing into the paver. In addition, once the paver has established contact with the truck, the truck driver should apply only enough pressure to the brakes to keep the truck in contact with the paver.
- In some cases, particularly if the mix is very tender, screed marks can be eliminated by not stopping the paver between truckloads of mix. This can be accomplished by using a window elevator or material transfer vehicle to deliver mix to the paver hopper. If dump trucks are used to haul the mix, however, it is generally better to stop the paver between truckloads of material (stopping and restarting the paver as quickly as possible) instead of allowing the paver operator to run the hopper dry, reduce the head of mix in front of the paver screed, and increase the opportunity for truckload-to-truckload segregation.
- To achieve uniform surface texture, the elevation and angle of attack of the screed extensions must be matched to those of the main screed. Longitudinal screed marks caused by improperly setting the elevation of the extensions can be eliminated by correcting the position of each extension relative to that of the main screed. Adjustments to both the vertical position and the angle of attack of the extensions may be needed. These adjustments should be made whenever hydraulic or rigid extensions are used.

**(c) Effects on Long-Term Pavement Performance**

Transverse screed marks generally are not detrimental to the durability of the mat. They may, however, affect the ride by creating a bump whenever the marks cannot be completely rolled out by the compaction equipment. In many cases, the screed marks have less of an effect on the performance of the mix than does the slowdown and startup of the paver when the operator attempts to keep it moving as the empty truck pulls away and the loaded truck backs into the hopper.

Longitudinal screed marks indicate that the level of the mix under the screed extensions is different from that under the main screed. If the screed marks are severe, differential compaction may occur across the mark or “joint”, with the compaction equipment initially riding on the higher mat. The marks can leave a ridge in the mix if they cannot be completely rolled out.

### **Screed Responsiveness**

As the thickness control cranks on the screed are changed, the screed’s angle of attack increases or decreases. As the paver moves forward to place the mix, the screed moves up or down to the new equilibrium point for the newly set mat thickness. When the screed fails to respond to changes in the setting of the thickness control cranks, the operator is unable to alter the depth of the layer being placed. The paver also loses its inherent ability, through the principle of the floating screed, to provide the self-leveling action needed to place a smooth asphalt mat.

#### **(a) Causes**

- An extremely high paver speed -more than eighty-three (83) feet per minute for thick lifts or more than fifty (50) feet per minute for layers more than two and a half (2.5) inches thick- may cause a lack of responsiveness of the screed. The mechanical condition of the screed affects its ability to react. The screed riding on its lift cylinders or loose connections on the thickness control cranks will cause the screed to be unresponsive. If automatic grade controls are used, an incorrect sensor location will render the screed unable to react to input signals from the grade sensors.
- If the maximum aggregate size used in the mix is too great compared with the depth of mix being placed, the screed will ride on or drag the largest aggregate pieces. As a result, the screed will be unable to change its angle and will thus be unresponsive to changes in the thickness control settings. Variations in mix temperature will also cause the screed to be unresponsive to changes in the angle of attack because the mix stiffness variations themselves will cause the screed to continually seek new equilibrium levels for the forces acting on it.

#### **(b) Solutions**

- The paver and screed must be in good operating condition. The sensor for automatic grade controls must not be located either at the tow points or behind the pivot points of

the screed; rather, it should be located in the area between one-third ( $1/3$ ) and two-thirds ( $2/3$ ) of the length of the leveling arms. If the mix texture is uniform (indicating a proper relationship between course thickness and maximum aggregate size), the screed will be able to respond to changes in the thickness control settings.

**(c) Effects on Long-Term Pavement Performance**

An unresponsive screed causes a rough asphalt mat. The screed is unable to react to manual changes in the thickness settings. It also loses its ability to self-level on an existing pavement surface because it cannot reduce the thickness of mix placed over the high points in that surface and increase the thickness placed in the low areas. Thus the rideability of the course being placed can be affected significantly if the paver screen is unresponsive.

**Image below illustrates effect of improper Screed Temperature.**



**Poor Precompaction**

A modern asphalt paver is normally equipped with a vibratory screed. This type of screed allows the mix to be partially compacted as it passes beneath the screed. Depending on such variables as forward paver speed, layer thickness, mix temperature, and ambient environmental conditions, the density of the asphalt mixture measured behind the screed before compaction is usually in the range of seventy to eighty (70-80) percent of the theoretical maximum density (a voidless mix).

A few pavers are equipped with combination screeds, which have both tamper bars and vibrators. At slow paver speeds, the combination screed typically achieves greater compaction of the mix than is obtained with the vibratory screed alone. At paver speeds greater than twenty five (25) feet per minute, however, the increased compactive effort achieved with the tamper bar is typically lost, and the degree of compaction obtained is similar to that achieved with a simple vibratory screed.

**(a) Causes**

- The amount of precompaction achieved with the screed decreases as the paver speed increases. Precompaction generally increases slightly as the frequency of the screed vibration increases. Precompaction decreases significantly, however, if the screed is riding on the screed lift cylinders, thereby limiting the available compactive effort. The level of precompaction obtained is also limited if the mat is too thin for the maximum aggregate size used in the mix (less than twice the largest size aggregate), if the mix being placed is too cold, or if the base on which the new layer is being laid is soft and yielding.

**(b) Solutions**

- Decreasing the paver speed and increasing the frequency of vibration of the screed should, within limits, increase the level of precompaction achieved during the laydown operation. It is also possible on some pavers to increase the amplitude of the vibration in order to increase the impact force of the screed on the mix. Proper maintenance of the screed helps as well in obtaining a uniform compactive effort from the screed.

**(c) Effects on Long-Term Pavement Performance**

As long as the required density level is obtained using conventional rollers behind the paver, the level of precompaction accomplished by the screed will not affect the long-term performance of

the AC layer. It may be possible, however, to reduce the number of roller passes needed to meet the density and air void content criteria if the amount of precompaction obtained by the screed is higher. In addition, increased precompaction density can reduce the amount of differential compaction that occurs in low spots and rutted areas.

### Surface (Auger) Shadows

Surface (auger) shadows are dark areas that appear in the surface of an AC mix. In most cases, the shadows cannot be seen until sometime after the pavement has been used by traffic and some of the asphalt cement film has been worn off the exposed aggregate particles by the vehicle tires. Surface shadows are seen most easily when the sun is low on the horizon and the pavement is viewed when looking toward the sun. The shadows are also visible when the pavement surface is damp or when the surface is viewed from the shoulder of the roadway at night and vehicle headlights are shining on the surface.

In severe cases, surface shadows may be visible immediately behind the screed during the laydown operation. Even in this latter case, the shadows will disappear when



the mix is being compacted by the rollers, only to be visible again later under the conditions described above. The shadows may be completely across the lane width being placed, or they may be only partially across the width. The extent of the shadows depends on how the paver is operated, particularly the portion of on to off time of the augers on each side of the machine.

#### (a) Causes

- Surface shadows are caused primarily by overloading of the augers on the paver. If the head of material in the auger chamber is large enough to “bury” the augers, the screed will react to the variable forces acting on it. The spacing between the shadows will normally correspond to the starting of the augers when operated in a stop/start

manner. Whenever the amount of mix in front of the screed is at or above the top of the augers, the shadows will be formed and seen later in the pavement.

- On most pavers it is possible to adjust the distance between the screed and the tractor unit. This is accomplished by unbolting connections on the leveling or tow arms of the paver and moving the tractor forward (or backward) while the screed remains stationary on the pavement surface. Depending on the make and model of the paver, there is typically a four (4) inch length of slide for the screed connection. The severity of surface shadows may increase with the screed in the back position – when more mix is being carried in the auger chamber and the augers are being overloaded.
- The shadows are thought to be the result of a slight increase in mix density caused by the restating of the augers and the subsequent forcing of additional mix under the screed. There is no difference in surface texture associated with the location of the surface shadows; they can be seen only from an angle. Their intensity often increases when a tender mix is being laid.



#### (b) Solutions

- The AC mixture carried in the auger chamber should be maintained at a level near the center of the auger shaft. This means the flow gates should be set so that the augers operate as close to one hundred (100) percent of the time as possible and stopping and starting of the augers is minimized. In no case should the top of the augers be completely covered with mix. Further, the location of the screed should be set as far forward as possible so that the amount of material in the auger chamber is reduced and the head of material in front of the screed is kept to a minimum. The screed should not be set in the back position unless a large-stone mix one in which the maximum size of the aggregate is more than one and a half (1 1/2) inch is being placed.

**(c) Effects on Long-Term Pavement Performance**

Surface shadows are not necessarily detrimental to the performance of the mix, except for a minor effect on rideability. The difference in the density of the mix in areas with and between shadows is generally not great enough to be determined accurately. The main concern with surface shadows is the visual appearance of the mix to vehicle drivers.

**Joint Problems**

Poor transverse joints are associated either with a bump at the joint, a dip in the pavement surface several feet beyond the joint, or both. Poor longitudinal joints between passes of the paver are usually characterized by a difference in elevation between the two lanes, by a raveling of the asphalt mix at the joint, or both. The area adjacent to the longitudinal joint is usually depressed below the level of the surrounding pavement surface.

**(a) Causes**

- Joint problems are caused by poor construction of the joint, inadequate compaction of mix placed along the joint, improper start-up procedures when paving resumes after a stoppage, or improper construction and removal of tapers.

**(b) Solutions**

- One key to a good transverse joint is to construct the joint at the end of the paving day at a location in the mat where the layer thickness is constant. This means the compacted thickness of the mat at the end of the paver run is the same as that of the previously placed mat.
- At the start of paving the following day, the paver screed should be placed on blocks on the cold side of the transverse joint. The thickness of the blocks should be related to the



depth of the course being laid – approximately one quarter ( $1/4$ ) inch thick for each one (1) inch of compacted layer thickness. The front edge of the paver screed should then be placed directly over the vertical face of the joint. Once the paver pulls away from the joint, the right amount of mix should be in the right place, and only minimal raking, if any, normally needs to be done. The mix at the joint should then be compacted as quickly as possible.

- For longitudinal joint construction, it is extremely important to compact the edge of the first lane properly. Doing so requires that the vibratory or static steel wheel roller hang out over the unsupported edge of the mat by about six (6) inches. This practice provides the most compactive effort along the unconfined edge without causing undue lateral displacement of the mix along the edge of the pavement.

- When placing the second (adjacent) pavement lane, the end plate on the paver screed should overlap the first lane by one to one and a half ( $1-1\frac{1}{2}$ ) inches. Minimal raking, if any, should be done on the mix placed over the first lane. The



rollers – vibratory, pneumatic tire and static steel wheel – should operate on the hot side of the joint and extend over the joint on the cold side by approximately six (6) inches. The same number of roller passes should be made over the longitudinal joint as over each point in the interior of the AC mat.



**(c) Effects on Long-Term Pavement Performance**

A poor transverse joint will not affect pavement performance to any significant degree if proper density levels are obtained by the compaction equipment. A poor ride will usually be the only negative result. An improperly constructed longitudinal



joint, however, can seriously decrease the serviceability of the pavement structure. A poorly placed and compacted joint will ravel and cause one side of the joint to be lower than the other. If the density level is too low, the whole pavement layer thickness at the longitudinal joint may eat away under the action of traffic. A poor joint will also be porous, allowing water to enter the underlying pavement courses.

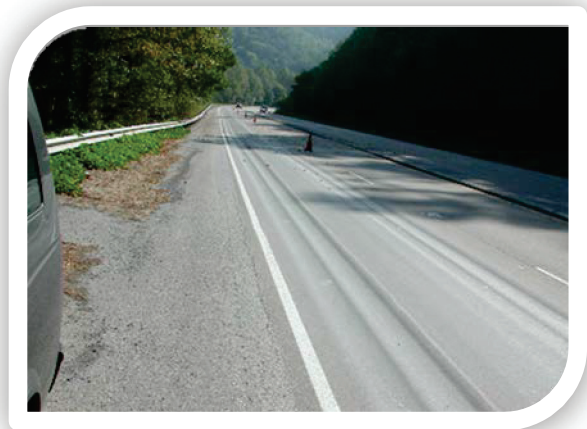
### Shoving and Rutting

Shoving of an AC layer is displacement of the mixture in a longitudinal direction. Such displacement may take place during the compaction operation or later under traffic. In most cases, shoving during construction is accompanied by a large bow wave in front of the breakdown roller, particularly if that roller is a vibratory or static steel wheel machine. Shoving may also occur in conjunction with mix checking if the mix is tender enough as a result of faulty aggregate gradation or excess fluids (asphalt binder or moisture) content. Finally, mat or mix shoving can occur at the reversal point of the rollers, especially at the location closest to the paver.

Rutting, shows displacement of the mixture in both vertical and transverse direction. Rutting occurs when heavy traffic passes over an unstable mix. In a few cases, the rutting is purely vertical (consolidation rutting). In this situation, the mix was not adequately compacted at the time of construction, and the traffic loads are essentially finishing the compaction process. The most common form of rutting is transverse distortion – the mix distorts or shoves transversely as a result of lateral flow of the mix under applied traffic loads.

#### (a) Causes

- Shoving and rutting are due primarily to an unstable AC mixture. This instability can be caused by the same variables that are responsible for checking – an excess of fluids (asphalt binder or moisture) in the mix, a hump in the fine aggregate grading curve, or the properties of the aggregate and the asphalt cement. A mix that has a high Marshall or Hveem stability may still distort longitudinally under the compaction equipment and later both longitudinally and transversely under traffic. Shoving and rutting can be highly prevalent when a sand mix is placed in a thick layer (more than one and a half (1 1/2) inch at a high temperature (more than 280°F). Further, thicker lifts in proportion to the maximum-size aggregate used in the mix will tend to shove more than thinner lifts with the same aggregate size and grading.
- Improper roller operation, particularly sudden reversal of the roller, can also contribute to the shoving of the mix during construction. If a vibratory roller is



run at too great a speed and the impact spacing is too far apart, the mat may develop a washboard effect, where the peak-to-peak distance is equivalent to impact spacing. Washboarding or shoving is more likely to occur at normal frequencies but at high speeds where the impact force is greater. If a pneumatic tire roller with high tire pressure is used for breakdown compaction, a tender mix may shove laterally under the tires. Shoving can occur under any roller that is operated improperly.

- Another possible cause of shoving is an excess of tack coat material that may be pulled into the mix. In a similar manner, excess asphalt from a bleeding underlying surface or from joint filler material can be pulled into the mix and increase its fluidity and tenderness. Shoving may occur as well when the underlying surface is dusty or dirty – a slippage failure.



#### (b) Solutions

- The solution to a mix that shoves under the compaction equipment is to increase its internal stability. This can be accomplished by reducing the fluids content (asphalt or moisture or both) of the mix, but only after determining the effect of a change in asphalt binder content on the mechanical properties of the mix. The internal friction can be increased by lowering the mix temperature. Alternatively, the internal friction among the aggregate particles can be increased by changing the aggregate gradation or increasing the amount of angular (crushed) particles in the mix.
- The compaction process for a tender mix should be changed, as discussed above under checking, to obtain sufficient density at the time of construction. An increase in the density achieved during the construction process will generally reduce the amount of shoving and rutting that may occur later under applied traffic. Sand mixes, because of their inherent tender nature, should be placed in several thin layers instead of one thick layer when used as base or binder courses.

- The compaction equipment should be operated properly so as to reduce the opportunity to displace the mix during the rolling operation. Further, if the underlying pavement surface is dirty, it should be cleaned and a proper tack coat applied.

### (c) Effects on Long-Term Pavement Performance

Mats that tend to shove under the compaction equipment are basically unstable. These mixtures will usually continue to distort under traffic, both longitudinally and laterally. Shoving of the AC mixture during construction is a strong indication that the pavement will rut later and not perform properly under traffic.

### Bleeding and Fat Spots

Bleeding of an asphalt mixture occurs when the asphalt cement flows to the top of the mix surface under the action of traffic loading. Bleeding is often seen as two flushed longitudinal streaks in the wheel paths of the roadway. Fat spots in an asphalt mixture are isolated areas where asphalt cement has come to the surface of the mix during the laydown and compaction operation or later under traffic. These spots can occur erratically and irregularly, or they may be numerous and in a fairly regular pattern.

#### (a) Causes

- Fat spots are caused primarily by excessive moisture in the mix. The problem is more common with mixtures that contain a high percentage of fine aggregate (oversanded mixes) and those that contain aggregates with a high porosity. If all the moisture in the coarse and fine aggregate is not removed during the drying and mixing operation at the asphalt plant, the moisture vapor will force asphalt cement to the surface of the mix behind the paver as the moisture escapes from the mix and evaporates. Fat spots occur more frequently when aggregate stockpiles are wet or when the moisture content varies in



different portions of the stockpiles. Fat spots sometimes occur in areas where petroleum products, such as oil and diesel fuel, were spilled onto the pavement surface prior to overlay or have contaminated the mix. In addition, fat spots can be associated with segregated areas in the mix. If the mix deposited on the roadway by the paver is segregated, areas in which excess asphalt cement is present in the mix can result in free binder material on the top of the layer being placed.

- The causes of bleeding normally fall into two categories. The first is an excess of fluids in the asphalt mixture – either asphalt cement or moisture or both. Under traffic, the extra moisture and asphalt cement will be pulled to the surface by the passage of vehicle tires. This bleeding phenomenon usually occurs on new mix and during hot weather when the viscosity of the asphalt cement is at its lowest level. Typically the bleeding occurs shortly after traffic is allowed to travel over the fresh mix – while there is still some moisture in the mix and while the viscosity of the asphalt cement binder is still relatively low.
- Bleeding may also be associated with a lack of adequate space in the mix for the asphalt cement. If the VMA content and air void content of the mix do not provide enough room for the binder material, bleeding can occur as the mix is densified by traffic, both shortly after construction and later. The traffic compaction process will decrease the air void content of the mix and may, in turn, squeeze some of the asphalt cement out of the mix. The “extra” asphalt will appear as a longitudinal streak or fat spot throughout the length of each wheelpath.
- One additional possible cause of bleeding is the condition of the pavement layer on which the new mix is placed. If the underlying



#### **(b) Solutions**

- Variations in the asphalt mix temperature behind the paver indicate that the moisture content of the mix may also be variable. Where moisture has evaporated, the

temperature is lower. This latter phenomenon can contribute to both the bleeding of the mix during construction. It is important, therefore, that the aggregate used in the mix be relatively dry and that the moisture content of the mix upon discharge from the asphalt plant be as low as possible, but not more than half of one (0.5) percent. Extra care needs to be taken in drying when producing mixtures that incorporate highly absorptive aggregate.

- Bleeding problems caused by excess asphalt cement in the mix can most easily be solved by reducing the asphalt content, consistent with other properties of the mix, such as air voids, VMA, and strength or stability. Bleeding problems that occur in conjunction with pavement rutting usually can be solved, however, only by a complete redesign of the asphalt mixture, with emphasis on proper air void content and VMA criteria.

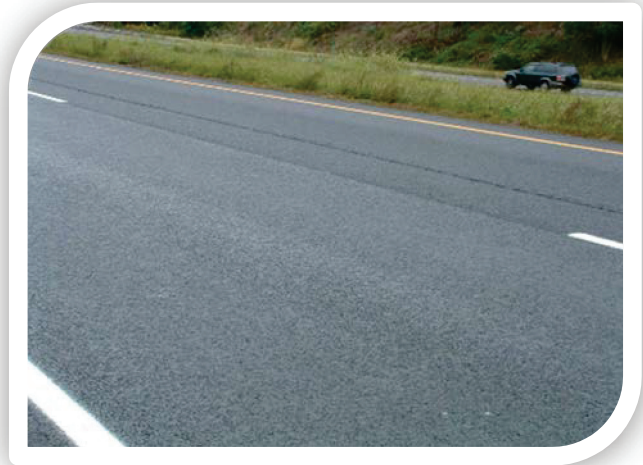
#### **(c) Effects on Long-Term Pavement Performance**

Occasional fat spots in the mix should not affect the ultimate durability of the pavement to a significant degree. A large number of fat spots or bleeding in the wheelpaths does affect pavement performance, however, because of variable asphalt and air void content in different parts of the mix. In addition, other mix problems, such as shoving, rutting and loss of skid resistance, may occur in a mix that contains many fat areas or bleeding in the wheelpaths. The design of the asphalt mixture, the operation of the asphalt plant (more complete removal of moisture), or both should be checked to ensure that the mix produced will provide adequate pavement performance under vehicular loading.

## Roller Marks

During the compaction process – whether vibratory static steel wheel or pneumatic tire rollers are used – longitudinal creases or marks are left in the surface of the mix. Once the mix has cooled to a temperature range of 160°F-140°F, these marks are typically removed by the finish roller. Roller marks are indentations that remain in the surface of the mix after the rolling has been completed.

Roller marks may also exist in the asphalt surface when any roller is parked on the hot mat for a period of time or when a vibratory roller is vibrated in place. Particularly when used in the breakdown position, pneumatic tire rollers can leave visible longitudinal marks that can still be seen after the finish rolling has been completed. Vibratory washboard marks may be visible if that roller is operated at an improper vibratory amplitude, frequency setting, or speed.



### (a) Causes

- Roller marks can be an indication that the proper number of roller passes has not been made over the mix. If the compaction process is halted before the required amount of rolling has been completed or if the mix cools before the compaction process has been finished, the longitudinal marks or creases made by the rolling process will remain in the surface of the mix.
- Roller marks left in an asphalt layer also may indicate a tender mix. The roller operator will normally be unable to remove all the marks left by the compaction equipment if the mix is tender or unstable. A tender mix usually will not support the weight of the finish roller until it has cooled to the point at which the viscosity of the asphalt cement has increased enough to stiffen the mix. By the time the mix has decreased in temperature to this point, however, the required level of density can generally no longer be achieved because the mix has lost its workability. For this reason, the roller marks or indentations left during the breakdown and intermediate roller passes usually cannot be removed during the finish rolling process. All of the asphalt cement, aggregate, and mix properties that contribute to the formation of a tender mix, as discussed above, also contribute to the inability of the finish roller to eliminate roller marks.

**(b) Solutions**

- If the cause of roller marks is inadequate compaction, additional roller passes should be made with the breakdown, intermediate, or finish rollers to properly densify the mix. The solutions for inadequate compaction related to mix design deficiencies all involve changes to the mix design and to the production of the mix at the asphalt plant. Asphalt cement quality and content, aggregate properties and characteristics, and mix temperature all play a significant role in the workability and stability of the asphalt material under the compaction equipment. Roller marks normally cannot be removed from a tender mix until the mix temperature has decreased to a relatively low level – usually less than 160°F.
- Sometimes it is possible, depending on environmental conditions and the properties of the mix, to remove roller marks left in the mix by using a pneumatic tire roller. If the surface of the mix is hot enough (140°F) or more, several passes with a pneumatic tire roller can be made to “iron out” the surface of the pavement. Finally, roughness or washboarding caused by incorrect operation of a vibratory roller should be eliminated by using proper operating techniques with this equipment.

**(c) Effects on Long-Term Pavement Performance**

Roller marks are normally an indication that the proper level of compaction has not been achieved. In terms of ultimate paving durability, the air void content or density of the mix is the single most important characteristic that governs the performance of the asphalt mixture under traffic. If the air void content of a dense-graded mix is high – the density is too low – the pavement generally will not perform well under traffic.



## Segregation

Segregation is the separation of the coarse aggregate from the rest of the mix in an AC mix. Segregation results from mishandling the mix at any of several points during the mix production, hauling, and placing operations. When segregation occurs in a paving project, it is likely to lead to forms of long-term pavement distress such as wavy surface and poor compaction. It can occur as the mix is delivered from the asphalt plant to a surge silo, as the mix is deposited into the haul truck from the silo, and as the mix is discharged from the truck into the paver hopper. Segregation that is evident behind the paver screed generally takes one of three forms: it may consist of areas of coarse aggregate (rock pockets) that occur randomly across the length and width of the layer; it may occur at a transverse location across the width of the lane (truckload-to-truckload segregation); or it may occur along one side of the paver width (longitudinal or side-to-side segregation).



### (a) Causes

- The cause of segregation behind the paver is directly related to the type of segregation involved. Rock pockets are generally caused by improper handling of the aggregate in the stockpiles, cold-feed bins or storage of the AC at the asphalt plant. They seldom occur when a batch plant is used to produce the mix (without a silo), because the screens and hot bins in the plant recombine any segregated material before it is fed into the pugmill. Further, the pugmill blends all the aggregates together and normally eliminates any segregation that might have occurred previously. If a silo is used on a batch plant, however the mix may segregate for all the same reasons that affect a mix produced in a drum-mix plant and passed through a surge or storage silo.
- Rock pockets and random segregation are occasionally found on the roadway when the mix was manufactured in a drum-mix plant. If the loader operator places a bucketful of segregated aggregate in a cold-feed bin, that material can pass through the drum, surge silo, haul truck and paver without being completely mixed in with the other aggregate. This is because the drum-mix plant operates on a continuous-flow instead of a batch

basis. If the aggregate in the cold-feed bins is segregated, that material will show up on the roadway in a random pattern both transversely and longitudinally.

- Some mixes are more prone to segregation than others. Asphalt mixes that have large maximum size coarse aggregate (1in. or greater), have low asphalt cement content, or are gap-graded will tend to segregate more readily when handled than a dense-graded mix containing optimum asphalt content and a smaller maximum-size coarse aggregate.
- Segregation that occurs on one side of the paver (side-to-side segregation) when a batch plant without a silo is used to produce the mix is normally caused by improper loading of the haul truck from the pugmill. If the mix is not loaded in the center of the width of the truck bed, the coarse aggregate particles in the mix may roll to one side of the truck and accumulate along that side. When the mix is delivered to the paver hopper, the segregated mix will be placed on the roadway along the same side, and the segregation will appear as a longitudinal streak on one side of the paver only.
- Segregation that occurs on one side of the paver when a batch plant with a silo or a drum-mix plant is used to produce the mix is typically caused by improper loading of the mix into the surge silo. As the mix is deposited into the silo from the conveying device (slat conveyors, belt conveyor, or bucket elevator), the mix is thrown to one side of the silo, and the coarse aggregate particles are separated from the finer materials. When the silo is emptied, the coarse aggregate is deposited on only one side of the truck. This segregated material then passes through the paver and is seen on one side of the mix after laydown. Further, as with a batch plant, if the truck is not loaded in the center of its width under the silo, rolling of the coarse aggregate particles may occur, and longitudinal segregation will then appear on one side of the new mat.
- Truckload-to-truckload segregation has many potential causes. The most common is improper loading of the haul truck from the silo. If mix is placed in the truck bed in one drop from the silo, the coarse aggregate particles in the mix have a tendency to run to both the front of the bed and the back tailgate. This rolling of the coarse aggregate is exacerbated if the plant operator continuously opens and closes the silo gates near the end of the truck-loading procedure to ensure that the full weight of mix is placed on the truck.
- Some believe that truckload-to-truckload segregation can also be caused by improper discharge of the mix into the silo. Mix that is dribbled into the silo from the conveying

device is said to be susceptible to segregation inside the silo. Even if this occurs, the mix that is segregated in the silo will appear only as random rock pockets in the layer behind the paver, instead of in a systematic manner between truckloads of mix delivered to the paver. Thus it is doubtful that any segregation of the mix that occurs during the continuous process of loading the silo will appear on the roadway in a discontinuous pattern – only at the beginning or the end, or both, of a truckload of mix.

- Temperature segregation of the mix has also been shown to be a problem. The mix cools more quickly near the edge, bottom, and top of the truck during haul. This cooler material is not always remixed with the hotter HMA, leading to temperature segregation during the laydown operation. The result can be more variability in density during construction and a non-uniform surface. This problem can be monitored by infrared technology.

#### **(b) Solutions**

- The solution to each type of segregation is related to its cause. For random rock pockets that appear intermittently in the mat, the method of stockpiling the coarse aggregate at the asphalt plant and the charging of that material into the cold-feed bins by the front-end loader should be checked to ensure that proper aggregate handling techniques are used. Further, all points in the mix-production system at which coarse aggregate particles might accumulate should be inspected to determine whether the flow of the coarse and fine aggregate pieces is uneven. A batcher should be used at the top of the silo to direct the mix into the center of that piece of equipment.
- For longitudinal (side-to-side) segregation, the loading of the haul truck from the batch plant pugmill or from the silo at either the batch or drum-mix plant should be monitored to ensure that the mix is being delivered into the center of the width of the vehicle. When a drum-mix plant is used to manufacture the mix and the segregation problem is used to manufacture the mix and the segregation always appears on one side of the paver, several trucks should be loaded at the silo while facing in the opposite direction from their normal loading procedure. When the mix is passed through the paver, the longitudinal segregation should change sides – go from one side of the paver lane to the other. If the transverse position of the longitudinal segregation does change (and it should), the solution to the side-to-side segregation problem must take place at the top

of the silo. The mix deposited into the silo from the conveying device must be directed into the center of the silo instead of to one side, so that the coarse aggregate particles in the mix are not thrown to only one side of the silo. If the transverse position of the longitudinal segregation does not change, the segregation is probably caused by a paver problem.

- Most truckload-to-truckload segregation can be reduced significantly by using multiple drops of mix to load the haul trucks. If a tandem-axle truck is being loaded, at least three different drops of mix should be made – into the front of the truck near the front bulk – head, into the back of the truck near the tailgate and into the center of the truck bed between the first and second drops. If a larger truck is used, additional drops of mix should be made – the first into the front of the truck bed and the second near the tailgate. One of the main solutions for truckload-to-truckload segregation is to minimize the distance the coarse aggregate particles can roll. This is accomplished by making multiple drops of mix into the truck.
- The plant operator should be prohibited from topping off the load of mix at the end of the loading process. Each time the silo gates are opened and a little bit of mix is dribbled into the truck, the coarse aggregate particles will tend to separate from the finer material. This problem can be eliminated only by preventing it from occurring.
- If segregation does take place during the loading of the truck and there is an accumulation of coarse aggregate particles at the tailgate of the truck, at the front of the bed, or both, the amount of segregation that appears on the roadway can usually be reduced by proper unloading of the haul truck at the paver. First, the truck bed should be raised a short distance, before the tailgate of the truck is opened, so that the mix can shift in the bed and slide against the tailgate. This procedure surrounds any coarse particles that have rolled to the tailgate are with non-segregated mix. Instead of only the coarse aggregate being deposited first into the paver hopper, a mass of mix is discharged when the truck tailgate is opened, flooding the hopper with mix and typically incorporating the segregated coarse aggregate into that mass of AC mix.
- The operation of the paver can also increase or reduce the amount of segregation that occurs behind the screed. If the paver hopper is emptied of mix, if the slat conveyors are visible, and if the wings of the hopper are dumped after each truckload of mix, any coarse aggregate particles that have collected at the tailgate of the next truckload of

mix will be deposited into the bottom of the hopper and then carried directly back to the empty auger chamber in front of the screed. This segregated material will appear behind the screed as soon as the paver moves forward. This transverse segregation, therefore, does not really occur at the end of the truckload, but rather at the beginning of the next truckload of mix.

- Segregation can be reduced by keeping the hopper full of mix between truckloads. The mass of mix that floods the hopper from the haul truck will be blended with the mix already in the paver hopper. Any segregated material will be further incorporated in the mix that is pulled back to the augers by the slat conveyors and passed under the paver screed. The amount of truckload-to-truckload segregation can be decreased significantly, but not always eliminated completely, by good paver operating techniques. The problem should really be solved during the truck-loading procedure.
- The use of MTV's has also shown some benefit in reducing segregation. The MTV remixes the HMA, and this reduces aggregate segregation, as well as differential temperatures within the mix (also known as temperature segregation).

### **(c) Effects on Long-Term Pavement Performance**

Segregation can affect pavement durability directly by increasing the air void content of the mix in the segregated areas and increasing the potential for moisture damage. Further, the segregated locations are very susceptible to raveling and, if bad enough, to total disintegration under traffic. Segregation, whether in the form of rock pockets, longitudinal (side-to-side) segregation, or transverse (truckload-to-truckload) segregation, is extremely detrimental to the long-term performance of the pavement.

**Poor Mix Compaction**

The AC mixture should be compacted so that the in place air voids are at an acceptable level. If the air voids are above seven to eight (7-8) percent, the mix will be permeable to air and water and will not have the required durability. If the initial compaction results in air voids of approximately 4% or lower, the mix may become unstable under traffic after additional densification; the result will be shoving and rutting of the mixture. Most mixes require a significant level of compaction to reach the desired 7-8% or less air voids.

**(a) Causes**

- When the mix is too stiff or too tender, compaction is difficult. The primary cause of poor compaction is low design mix density (high design air voids). Other causes include inadequate underlying support, improper type and weight of rollers, improper tire pressure in rubber tire rollers, improper rolling procedure, improper mix design, mix segregation, moisture in the mix, variation in mix temperature and low mix temperature.

**(b) Solutions**

- Solutions to compaction problems include taking the necessary steps to ensure adequate support, producing an acceptable mixture and using satisfactory laydown and rolling techniques. When support is inadequate, the compaction requirements may have to be relaxed, or the mix may have to be redesigned to allow for satisfactory compaction.
- When asphalt content is too high, the mix may compact too easily, resulting in low air voids (which leads to rutting). When the asphalt content is too low, the mix may be stiff and difficult to compact to the specified density. A satisfactory mix design will produce a mix with optimum asphalt content that can be compacted with reasonable effort to required density
- Good laydown and rolling techniques are necessary for good compaction. Density can normally be increased by reducing the speed of the paver or rollers. Density can also be increased by increasing the weight and number of rollers. The compaction process must be adjusted to produce optimum density.

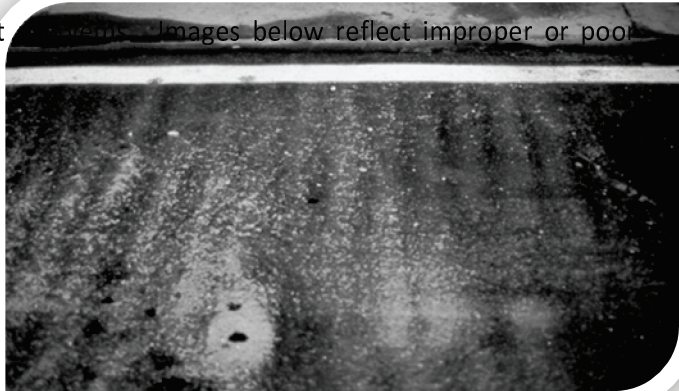
**(c) Effects on Long-Term Pavement Performance**

When the compaction is inadequate -more than seven to eight (7-8) replace air voids- the mix will be permeable to air and water. Water can flow through the AC and reduce the strength of the underlying base course. The high voids also result in excessive oxidation of the HMA, which leads to raveling, cracking and general deterioration of the AC over a period of time.

When the air voids are excessively low after compaction (less than 4% replace) the mix is likely to rut and shove under traffic. The low voids are the result not of too much compaction, but of an unsatisfactory mixture.

**Poor Roller Operation**

Poor Roller Operation can also lead to mat problems. Images below reflect improper or poor roller operation.



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